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Cancerous lung nodule detection in computed tomography images

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ABSTRACT

Diagnosis the computed tomography images (CT-images) is one of the images that may take a lot of time in diagnosis by the radiologist and may miss some of cancerous nodules in these images. Therefore, in this paper a new novel enhancement and detection cancerous nodule algorithm is proposed to diagnose a CT-images. The novel algorithm is divided into three main stages. In first stage, suspicious regions are enhanced using modified LoG algorithm. Then in stage two, a potential cancerous nodule was detected based on visual appearance in lung. Finally, five texture features analysis algorithm is implemented to reduce number of detected FP regions. This algorithm is evaluated using 60 cases (normal and cancerous cases), and it shows a high sensitivity in detecting the cancerous lung nodules with TP ration 97% and with FP ratio 25 cluster/image.

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1. INTRODUCTION

Lung cancer is one of the most relevant public health issues in United states, Europe and Middle East [1, 2]. Early Detection and treatment of this types of cancer is require to effectively overcome this burden. Chest X-ray considered a cheapest method as an initial detection of lung cancer. Computed tomography (CT) as a second diagnosis stage is the best imaging modality for the detection of small pulmonary nodules, particularly since the introduction of the helical technology [3, 4]. The CT images are a high resolution images with high amount of data storage. Therefore, researchers tries to help the radiologist to easily process these huge image and automatically detected the potential nodule lung cancers using computer aided diagnosis system (CAD) [5, 6]. Detection nodule lung cancer is one of the most difficult cases for the radiologist specially in CT images since the visual appearance of tumors is not clear or surrounding with parenchymal tissue in CT-Images [7, 8]. Therefore, the visual appearance for cancerous nodules have similar visual characteristics of normal tissues [9]. Therefore, this paper proposed a novel detection and classification method for cancerous cells. Three main stages are used to accurately detect the cancerous nodules in the CT lung images [10]. The paper present a brief description about the lung CT image in section 2. Then literature review section which presented in section 3. Proposed detection and classification algorithm is introduced in Section 4. Finally, discussion and conclusion are presented in section 5 and section 6 respectively.

2. DATABASE

The database that are used in this paper in downloaded from Cancer Imaging Archive (TCIA), which is organized into purpose-built collections of subjects [11]. This database has different kind of high resolution images of cancer type and/or anatomical site (lung, brain, etc.) in common. Moreover, the database include a huge dataset of MRI, CT, and X-Ray images that are stored as DICOM file format [12].

3. LITERATURE REVIEW

Many authors proposed different CAD techniques to help the radiologist in diagnoses lung cancer in CT images. One of these techniques is using Laplacian of Gaussian filter as in [13]. Their algorithm is divided to two main stages, transmission of high intensity and LOG Filter. These stages are applied calculate the contrast differences inside and outside region of interest. Snake algorithm is another enhancement and segmentation tool used to find the internal energy in CT image like Vivekanandan D. et al [14]. Messay et al. [15] implement local contrast enhancement filter that follow the nodule enhancement method to detect the chest radiographs. Dots, lines, and planes enhancement techniques are used by Li et al. [16]. Such these enhancement techniques can be implemented on specific shapes and suppress other objects. So, as an initial step the CT-Image is blurred then a Gaussian kernel filter (GKF) of a nodule size is implemented to detect the nodule. As final stage, multi-scales GKF are used as to find a match with the nodule size. Yamamoto et al. [17] used a statistical enhancement filter to enhance CT images. They implemented the Quoit Filter that has large ring and disk filters. Differential intensity value procedure is implemented in this algorithm between the internal and external disks in order to find a potential region of interest. Another segmentation algorithm is presented by Maciej Dajnowiec et al. [18]. Initially, an optimum threshold value was calculated based on different image data sets. Threshold algorithm then is implemented to segment lunge region from CT image. After that, connecting component labeling (CCL) is applied to detect remaining regions in the image. Therefore, lung nodule can successfully segmented but have lobes with nodules region.

On the other hand, CAD system is a powerful tool in detecting cancerous nodules in the CT images. Another CAD system to detect cancerous lung region is proposed by Lee et al. [19]. Authors implement GA to set a target position and also to match the best template image from previous data sets. Four generations every time are established based on grey level of Gaussian distribution. Algorithm sensitivity was 85% in detecting cancerous nodules in the CT-images. Other author like Opfer et al. [20] used distance transformation technique to improve the performance of CAD system. The distance transformations of various thresholds and subsequent crest line extraction are used enhance the CAD sensitivity. CAD system performance is slightly improved when using this technique since it produce large number of FP regions. Another CAD system is used by Moreover, Golosio et al. [21] to detect cancerous nodules in CT images. They used multi-adaptive threshold surface triangulation approach in the detection algorithm. The proposed algorithm show good sensitivity in detection cancer nodules but many detected FP are presents. K. Devaki et al. [22] develop a technique to accurately segment lung region from CT- images. The proposed algorithm can efficiently segment the lung regions from CT-images.

4. RESEARCH METHOD

Enhancement and detection of the cancerous nodules technique is proposed in this paper. The proposed method is mainly divided to three stages. Initially, the cancerous lung nodules will be enhanced using Laplacian filter. Then in the second stage, the average detection algorithm will be used to detect a potential cancerous lung nodule (PCLN) regions in CT-images. Final, five texture features are used to help in reducing number of detected FP regions. Figure 1, show the proposed algorithm stages.

4.1. Cancerous lung nodule enhancement

The fundamental operation needed to assist cancerous nodule in CT-image is contrast enhancement. In many image processing applications, the Laplacian filter is one of the simplest and effective techniques for intensity enhancement that presented in as (1). Laplacian filter improves contrast of the cancerous nodules in CT-image by applying the Laplacian mask of size 9 × 9.

$$S(x, y) = f(x, y) + c[\nabla^2 f(x, y)] \quad (1)$$

where S(x, y) is the intensity value for the processed image, f(x, y) the intensity value for the input image and c is consider as one in this paper.

Cancerous nodules appear on digitized CT as small regions, with intensity values higher than their surrounding background. The size of cancerous nodules is usually less than 4 mm [23]. So it is not easy to enhance the cancerous nodules regions since surrounding lung tissue makes the abnormality areas almost invisible. Therefore, the modified average filter is implemented to smooth the edges of the processed Laplacian enhancement image. This in case will slightly enhance the cancerous nodules regions to be easily detected in the next stage.

After extensive analysis of 60 cancerous CT images, we concluded that all cancerous nodules have grey scale values in the range from 80 to 230 [24, 25]. In accordance with these observations, each CT-image is processed using the modified average filter that presented on (2),

$$S_K = \frac{1}{mn}\sum_{j=80}^{230} r_j \qquad (2)$$

where Sk is the intensity value for the processed image, rj the intensity value for the input image and m and n are the mask size. After processing the Laplacian and modified average filter, the cancerous nodule regions become slightly brighter corresponding to the neighbor regions as shown in Figure 2. This will assist in detection the region of interest that will be discussed in the next section.

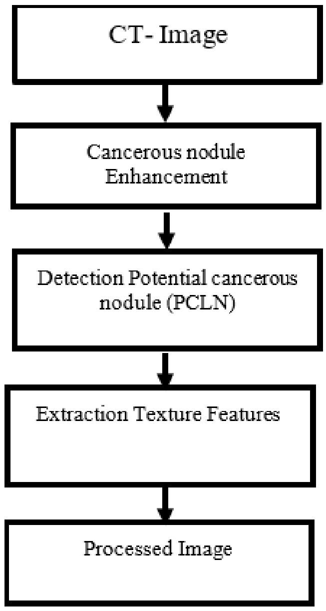

Figure 1. MC detection and classification

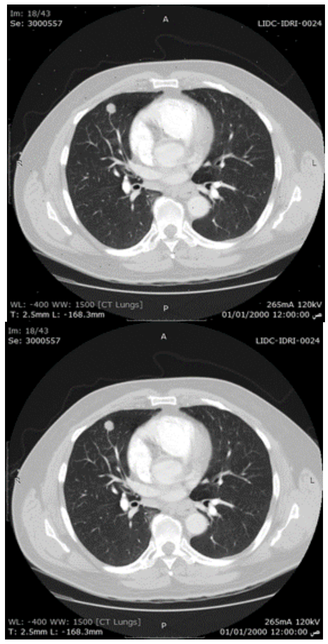

Figure 2. Cancerous nodule enhancement result

4.2. Potential Cancerous lung nodules

Cancerous nodules appear on digitized CT-images as small regions, with intensity values higher than their surrounding background. So in order to detect these region, two concentric circular masks are used as shown in Figure 3. When centered on the cancerous nodule, the inner masked region included the cancerous nodule while the outer masked region included the surrounding region. The inner and outer concentric circular mask's size are design based on CT-Image resolution. These masks were tested on 60 CT-image and they were effective in detecting all the suspicious regions in CT-Images. Detection the potential cancerous lung nodules (PCLN) cluster is designed based on the fact that the cancerous nodules are brighter than the neighbor pixels. Therefore, in order to select PCLN two conditions should be satisfied, average value for the inner mask should be greater than outer mask and the intensity pixel value of the center of the inner mask should be the highest intensity in the mask. After processing 60 CT-images using PCLN algorithm, it was noticed that all cancerous nodules in the CT-images are detected but many detected false positive (FP) regions as shown in Figure 4. This in case will reduce the sensitivity of the proposed CAD system. Therefore, texture feature analysis will be applied to reduce number of detected FP clusters and increase the sensitivity of this CAD system.

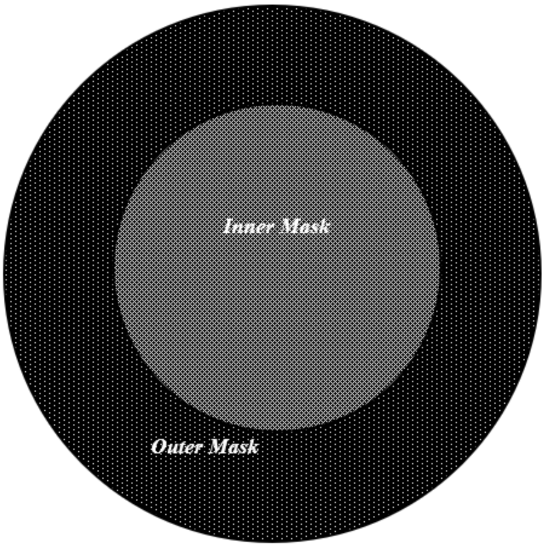

Figure. 3. Two concentric circular masks

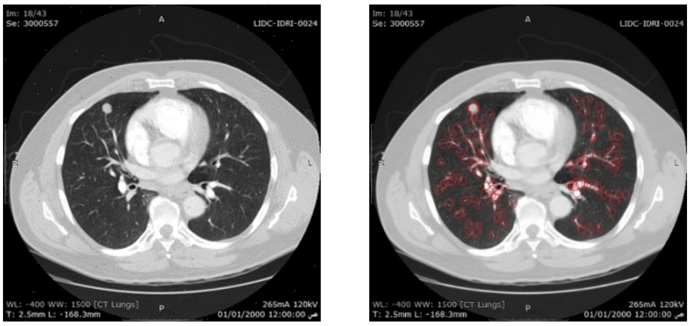

Figure 4. PCLN processing result

4.3. Texture feature extraction

Cancerous nodules are a small size less than 4 mm with a bright region comparing with the surrounding regions in the lung. So, in order to have a platform that can help radiologist in diagnosis these types of tumors, we need to focus on the view characteristics of cancerous nodules in CT-Images. As first step, the cancerous nodules are enhanced and a potential cancerous nodules algorithm is implemented to detect cancerous clusters in CT- images. Both algorithms are effectively detect the cancerous regions in the CT image but with high number of false positive (FP) regions. In this section, we implement a new approach to reduce number of FP regions using texture features. Having minimum number of FP region will enhance the performance of our CAD system.

First order texture features base is used in this paper to reduce detected number of FP regions. So, two datasets are generated to achieve this goal. TP dataset is generated using 223 expertly identified (actual) TP clusters and the second dataset which is FP dataset used 415 actual FP clusters. Then five texture features are calculated based on these datasets (TP and FP). These features are summarized in (4)-(8).

$$P(i) = \sum_{i=40}^{240} h(i)/MN \quad (3)$$

Where h(i) is the intensity histogram and M, N are the image region's height and width respectively.
- The modified mean feature

$$\mu = \sum_{i=40}^{240} iP(i) \quad (4)$$

– The modified entropy feature

$$E = -\sum_{i=40}^{240} P(i)\, log_2[P(i)] \tag{5}$$

– The modified standard deviation feature

$$\sigma = \sqrt{\sum_{i=40}^{240} (i-\mu)^2 P(i)} \tag{6}$$

– The modified third order of moment feature

$$M_3 = \sum_{i=40}^{240} (i-\mu)^3 P(i) \tag{7}$$

– The modified kurtosis feature

$$K = \sigma^{-4} \sum_{i=40}^{240} (i-\mu)^4 P(i) - 3 \tag{8}$$

The values of these features are presented as shown in Figure 5.

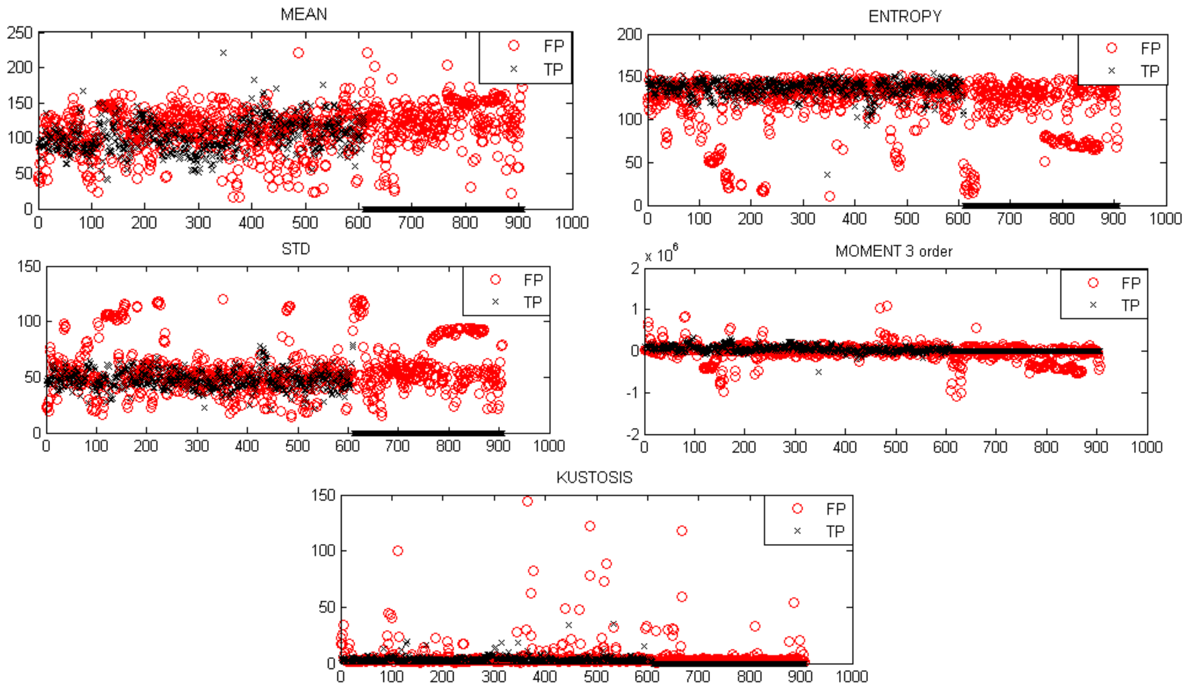

Figure 5. The first order feature

5. RESULTS AND ANALYSIS

The cancerous nodule enhancement and detection algorithm is applied on 60 CT-images. Then, five texture features are generated (Entropy, mean, STD, kurtosis and skewness) which were processed using statistical analysis to reduce the detected FP regions. The algorithm is subjectively evaluated using three radiologist, where number of detected FP regions are counted per image. Also TP percentage of each image is also recoded. Finally, the average of detected FP region and TP percentage is presented in the Table 1 after processing 60 CT-image. From Table 1, it is evident that our algorithm achieves a good performance in detecting cancerous nodules but still number of FP is slightly high. Figure 6 show the results of CT processing stages where the image processed using enhancement algorithm, then detection region of interest. Finally the texture feature analysis is implemented to reduce of the detected FP regions.

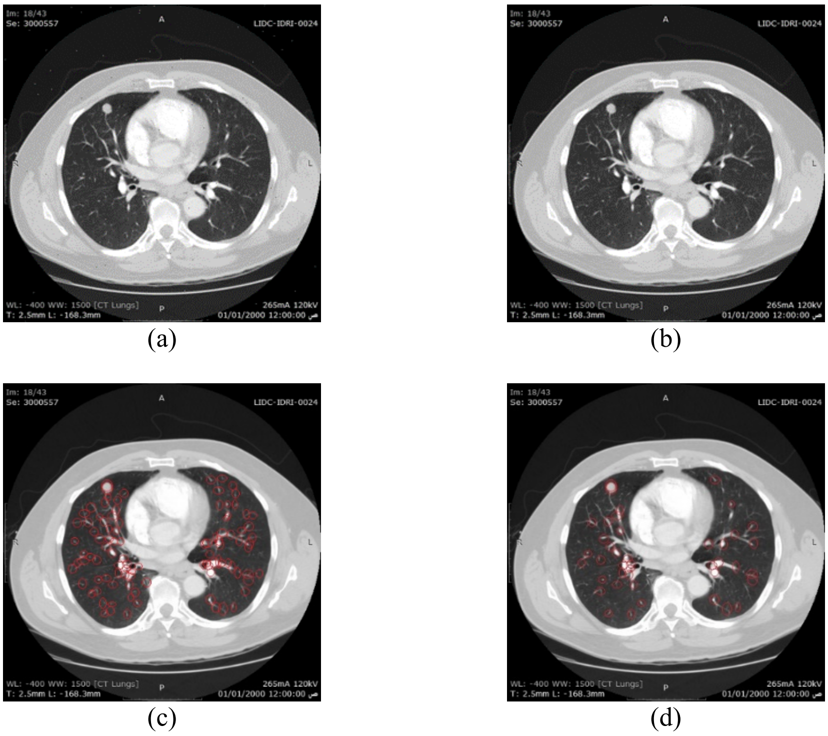

Figure 6. Accurate detection of cancerous; (a) original image, (b) image enhancement, (c) image with PLCN, (d) texture features analysis

Table 1. Image quality evaluation

	Average of detected FP region (cluster)	Average of TP (%)
Radiologist 1	28	97%
Radiologist 2	23	98%
Radiologist 2	24	96%

6. CONCLUSION

This paper presents the ongoing effort in enhancing and detecting the cancerous nodules in the CT images. This proposes algorithm is divided to three phases. The cancerous nodules are enhanced using the Laplacian filter. Then, the average filter is modified based on the lower and upper grey levels of the cancerous nodules in the CT images. This incase, slightly enhances the cancerous nodules in the mammogram images. In the second phase, the potential cancerous nodules regions are detected using multi statistical filter which results large number of FP regions. Finally, texture feature analysis is implemented to reduce the detected FP regions. As a result, the proposed algorithm is subjectively and objectively tested on 60 CT images and it shows that is algorithm can detect the cancerous nodules with an average rate 97.6% with FP regions of 25 cluster.

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